VOLUME XXX NUMBER 9 WHOLE NUMBER 258

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED MONTHLY
(*Ten numbers per year*)

November, 1936

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

Vol. XXX, No. 9 NOVEMBER, 1936 Whole No. 258

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SCIENCE AND PHILOSOPHY*

By Dayton C. Miller

SOME have doubted that the modern scientist possesses the idealism and faith necessary to the true philosophy. The scientist has been accused not only of not having any ideals of his own, but of being bent upon destroying the ideals of others. It may be incumbent upon the man of science to proclaim his philosophic conclusions as well as to announce the spectacular conquests of nature.

Existence is a struggle, and we are urged on by a hope of comfort and gratification and of a life of happiness. Every contemplative person, in the beginning, expects to formulate a philosophy of life which will indicate the ends to be striven for, and such that it will stimulate the motives of action and lead to the satisfaction of attainment. The term of existence is so short and incomplete that in this struggle the happiness acquired by an individual varies greatly and in a manner that often seems unjust. In order that life may be worth living for an intelligently thoughtful being, there must be something more than the momentary results of action, whether these be rewards or punishments; there must be a goal towards which integrated human accomplishment advances. In mathematical language, existence is an infinite series of individual lives, some positive, some negative, some of the first power and some of higher powers, but the sum of the series must approach a limit which is an ultimate good far transcending in importance any

*A portion of the Commencement Address at Case School of Applied Science, on June 1, 1936. Printed in *Science*, Oct. 2, 1936.

single term of the series, and the nature of which may be quite independent of that of any single term. This final sum of the series may be called an "ideal" which extends beyond the experiences of this life, which becomes an eternal verity, and constitutes reality, and our philosophy wishes to describe and even to explain it.

At Princeton University, forty-nine years ago, being determined to find a metaphysical basis for experimental science, I joined a group of perhaps ten seriously minded students who went once a week to the library of President James McCosh. We literally sat at the feet of this great Scotch-American philosopher while he expounded a philosophy of realism, opposed to idealism on the one hand and to agnosticism and materialism on the other. Those of my teachers who have impressed me above all other men are Dr. McCosh, Charles A. Young, the Princeton astronomer, and Cleveland's own Edward W. Morley, a triumvirate of profound and scientific philosophers.

Realism holds that there are real things and real "values". We cannot by pure reasoning prove the existence of either mind or matter. If we are ever to get hold of reality, we must seize it at once, and having whole-heartedly accepted it, we are to proceed to develop a system of philosophy which will be fundamentally scientific. I am prepared to adopt as the realities which constitute the universe three manifestations of absolute value: things which are eternally true—*science*; things which are intrinsically good—*ethics*; and things which are inherently beautiful—*esthetics*. There are not three different worlds of values; there is one universe of reality, a unity of the good, the true and the beautiful. And more, we must believe in the inherent and everlasting ability of mankind to progress towards an ultimate ideal or destiny, which requires that one's life be so ordered as to be in harmony with these eternal virtues. Such a life brings the greatest happiness and satisfaction.

It is not our observation or induction of these things that makes them realities; rather, we are sure we know them, we seek them, we cling to them, we are not satisfied with anything less nor indeed with anything else. This realistic philosophy is accepted in accordance with what the scientific man calls a "postulate"; others may well say it is accepted as a matter of "faith". Such

a system of philosophy is not new, in fact, it is one of the oldest systems.

The aim of life should be to secure the greatest development and manifestation of these qualities, and a life based upon such an ideal should bring the greatest happiness and satisfaction. Mere physical pleasure is a part of the reality of nature, and its pursuit is not only allowable but is laudable. However, the foolish man often overlooks the fact that nature is scientific and ethical in its very essence, as well as esthetic and epicurean, and that sooner or later he must submit to the inevitable consequences of his actions; the wise man knows that the most exquisite and satisfying pleasure comes to him who practices his enjoyments with regard to the unity and solidarity of nature. The universe does not keep its ethics in one compartment and its beauty in another, to be sampled as one selects; it is true throughout, it is beautiful throughout, and it is ethical throughout.

There is no conflict between science and real religion. It is not within the province of religion to circumscribe science nor to limit beauty. It is no part of the work of science to prove or to define religion. Ethics is just as real and just as fundamental as science, but not more so. The study of science should and usually does increase one's appreciation of the principles of ethics. The study of the laws of physics gives one an enhanced appreciation of the beauties of music, the subtlest of all the arts. The contemplation of any part of the universe of reality enlarges one's understanding of the whole.

I would quote from the writings of several physicists, with each of whom it has been my great privilege to be personally acquainted.

Henry A. Rowland, the first professor of physics of Johns Hopkins University, became the leading physicist of America. His love of truth held him in supreme control. He describes a scientific observer in the following words:

> I value in a scientific mind, most of all, that love of truth, that care in its pursuit, and that humility of mind which makes the possibility of error always present more than any other quality.

Lord Kelvin, England's greatest physicist, said:

> I believe that the more thoroughly science is studied the further does it take us from anything comparable to atheism.

The late Lord Rayleigh has said:

> It is a strange world, and perhaps the strangest thing of all is that we are here to discuss it. I may say that in my opinion true science and true religion neither are nor could be opposed.

The late Michael Pupin, of Columbia University, upheld upon every occasion the high ideals of science, and said:

> The worship of eternal truth and the burning desire to seek an ever-broadening revelation of it constitute the mental attitude which I call "idealism in science."

The late Dr. John A. Brashear, of Pittsburg, with whom I became acquainted in my college days, has always been a source of inspiration. In the making of astronomical instruments of precision he was the peer of any man of his time. Much as he loved and revered the science of astronomy—and surely no man ever loved it more—he said:

> The science most worth while in this world is that of extracting sunlight from behind the clouds and scattering it over the shadowed pathways of our fellow travelers.

His ashes, together with those of his life-long help-mate in good deeds, lie in the crypt under the great telescope of his own construction in Pittsburgh. The marble plate bears the inscription:

> We have loved the stars too fondly
> To be fearful of the night.

THE PHYSICAL STATE OF THE UPPER ATMOSPHERE

By B. Haurwitz

(*Continued from Page* 330)

V. Propagation of Electric Waves and Ionization

The propagation of radio waves over great distances of the earth cannot be explained as diffraction by the conducting surface of the earth. In this case the depletion of the wave energy would be much greater than is actually observed. Heaviside and Kennelly independently assumed that there exists in high levels of the atmosphere a conducting layer composed of ions or electrons or both where the waves are refracted or reflected back to the earth. This layer is known to-day under the name Kennelly-Heaviside layer, but a conducting layer in these heights was postulated long previously by B. Stewart and A. Schuster to explain the daily variations of the terrestrial magnetism.

When an electromagnetic wave travels upward and reaches the ionized layer the electrically charged particles are set in motion, according to the frequency of the wave, causing an increase of the wave-velocity v. This increase is proportional to the number N of ions or electrons per cm^3. Since the wave passes obliquely into the conducting layer the upper part of the wave-front travels faster than the lower part, the ray (which is perpendicular to the front) is bent, and if N increases sufficiently with height the ray will finally be reflected back to the earth. The wave-velocity v is, neglecting the magnetic field of the earth and absorption, given by the relations

$$\frac{v^2}{c^2} = \frac{1}{1 - \frac{N}{\pi}\frac{e^2}{mf^2}} = \frac{1}{n^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where c is the undisturbed velocity (i.e. the velocity of light), e, m, the charge and mass of the effective particles, $f = 1/T$, the frequency of the wave, and n the index of refraction. If z_0 is the height up to which radio waves penetrate, the equivalent height is given by

$$z' = \int_0^{z_0} \frac{dz}{n}$$

There are various methods of using wireless waves for the exploration of the conductivity or, as we may say now, ionization of

the upper atmosphere. We shall outline only the "critical frequency" method of Appleton[34]. Sender and receiver are in practice placed 50 m. apart, so that almost normal incidence of the wave at the reflecting layer is secured. The direct signal which travelled only 50 m. is used as a reference signal. The frequency is changed gradually and continuously from low to high frequencies and the signal received is recorded photographically. Fig. 4 shows a record obtained by Appleton and Naismith at Slough under winter noon conditions[35]. The short horizontal traces at A and B were produced by a 3 kc/sec. oscillator. The distance between two horizontal lines represents therefore an equivalent height of 25 km. A critical frequency is seen at 2.75 Mc/sec. After that the echo delay is greater. Other critical frequencies are found at 6.4 Mc/sec.

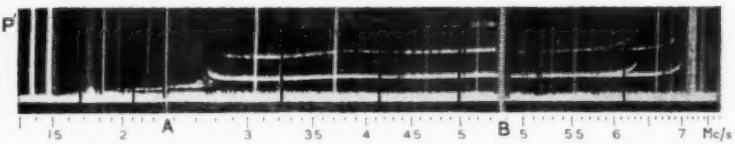

Fig. 4.—Record of critical frequencies, after Appleton and Naismith (Proc. Roy. Soc. Lond. A, vol. 150).

and 7.05 Mc/sec. The next higher line on the record is a signal which has been reflected twice at the ionized layer and once at the ground, and there is indication of a triple reflection in the upper atmosphere.

Systematic studies of the ionized layer have shown the existence of at least two layers, a lower E-layer roughly of 80-100 km. height and an F-layer at about 250 km. altitude. In fig. 4, 2.75 Mc/sec. represents the critical frequency of the E-layer. From the F-layer two echoes of critical frequencies, 6.4 Mc/sec. and 7.05 Mc/sec. are reflected. This "splitting" of the echo is due to the deflecting influence of the earth's magnetic field on the electric particles after they have been set in motion by the electro-magnetic waves. The value of v will be changed and double refraction and change of the plane of polarization of the wave occur (Kerr and Faraday effects). For the E-layer the energy connected with the ordinary wave is

much greater, in the range of frequencies used, than the energy of the extraordinary wave. E and F layers are present at any time of the day. During the daylight hours an intermediate layer is often more or less clearly found between E and F. This layer is called E_2 and the main layer is then referred to as E_1. The F-layer appears similarly subdivided giving an F_1-layer which is lower than the nightly F-layer. The main layer is during the daytime called F_2. It is higher than the F-layer during the night, 300 km. or higher[40]. The subdivision of the F-layer in daytime occurs more regularly than that of the E-layer[40]. Syam[36a] has reported the occurrence of a D-layer at 55 km. in India, but such a layer has not yet been recorded anywhere else. Also a G-layer has sometimes been observed above the F_2-layer[41].

It is necessary to keep in mind that these layers are not clearly separated from each other but that the change in ionization is more or less gradual. As the transition from troposphere to stratosphere is characterized by a different distribution of the surfaces of equal temperature which is by no means abrupt, so the division of the upper atmosphere into different layers is to be understood as a change in the distribution of surfaces of equal ionization. The layers are really regions where the iso-ionic surfaces crowd together.

Stetson found a definite connection between the strength of radio signals transmitted from one station to another and the hour angle of the moon.[37] His earlier explanation, that the moon has a negative charge, has been given up in favour of the interpretation as a tidal phenomenon of the upper atmosphere. (Rep. at the URSI meeting, Washington, D.C., 1936.)

The relation between magnetic storms and ionization has not yet been sufficiently explored to yield a clear picture. L. Harang[38] found from observations in Tromsö an increase of ionization during magnetic disturbances in the E-layer, decrease in the F-layer. The decrease in the F_2-layer has also been reported by Appleton and Ingram[39], and by L. V. Berkner for the F_1-region[40].

A positive correlation between ionization in the high atmosphere and the air pressure at the surface has been found by Martyn and Pulley in Australia[40a]. The authors explain it as an effect of the heating and cooling of the upper layers caused by a variable ozone content. The correlation of surface pressure and ozone in the lower

layers (20-40 km.) has been found before (Ch. VIII), and Martyn and Pulley assume that there is sufficient ozone and sufficiently large changes in the ionospheric regions to account for the necessary temperature changes.

The degree of ionization can be determined in the following fashion. A radio wave (Fig. 5) is sent up in the atmosphere, making an angle α with the vertical. Its path will be a straight line until it reaches the ionized layer E so that the angle of incidence is α. The layer E may be divided in such small layers that the ionization can be regarded as constant for each, but varying from one subdivision to the next.

According to the law of refraction we have:

$$n_i \sin \alpha_i = \text{const.}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where n_i, is the index of refraction and α_i the angle of incidence in the

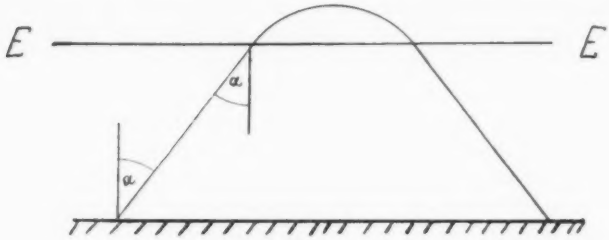

Fig. 5.

i^{th} layer. The index of refraction for the non-conducting layer is $n=1$, for the vertex of the ray n, the angle here is 90°. It follows that

$$n = \sin \alpha.$$

Combining this with eq. (3),

$$\cos^2 \alpha = \frac{N}{\pi} \frac{e^2}{mf^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

If the wave is sent vertically upwards, $\alpha = 0$, in eq. (5). Now, the critical frequency method gives the frequency f, which is just

still reflected, while a slightly higher one intrudes further up in the ionized atmosphere. We obtain thus as the maximum number of ions (or electrons) belonging to a critical frequency f_c

$$N_{\max} = \frac{\pi}{e^2} m f_c^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

This formula holds for the ordinary ray. The formula for the extraordinary ray is only slightly more complicated. Eq. (6) allows the computation of the maximum number of electrically charged particles per cm³ provided the nature of the particles is known. It may be noted especially that the critical frequency is proportional to the square root of the maximum ionization.

The noon value of the critical frequency is higher in summer than in winter in the E_1 and F_1 layers[35]. The ratio of the summer value to the winter value for the E_1-layer is 1.8, for the F_1-layer 1.86. The behaviour of the F_2-layer is quite different, there being apparently one maximum in March and another one in October-November.

As far as the daily variation is concerned, the critical frequency for the E_1- and F_2-layers has a maximum around noon in winter. The same holds in summer for the E_1- and F_1-layers. The behaviour of the F_2-layer is again quite different. The critical frequency here reaches a minimum after mid-day, with maxima in the morning (10.00) and in the afternoon (19.00-20.00)[35].

The distribution of observations over the earth is still too sparse to allow any conclusion to be drawn. An attempt to picture the geographic distribution of the F_1-layer has been made by Berkner[40].

The question whether the particles causing the conductivity in the ionosphere are electrons or ions has not yet been definitely decided; for the E-layer many investigators are inclined to assume ions, for the F-layers, electrons[42]. If the ionization of the E-layer is ionic the great majority of the electrons set free by the formation of ions would have to become attached to neutral particles since a a much smaller number of electrons than ions would account for the same critical frequency, owing to their smaller mass, as will be seen from eq. (6) (Cf. p. 356).

It seems to be established that the ionization is caused by the sun's ultra-violet radiation. Cosmic radiation would not give suffi-

ciently intense ionization[43]. The observations during solar eclipses are not favourable to the hypothesis that corpuscular solar radiation causes the ionization of the upper atmosphere [44, 45]. Since magnetic storms are caused by corpuscular solar radiation, the relation between magnetic storms and ionization should be much stronger than has been observed so far. Meteors[46, 47] and thunderstorms[46] seem to have a local ionizing effect. The main source of ionization must, however, be the ultra-violet radiation from the sun. The observations will be interpreted under this assumption[35].

According to Chapman we have then[48, 33] for the rate of maximum ion production

$$q_{\max} \sim \gamma S_\infty \frac{\cos \zeta}{H} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where γ is the number of ions produced by absorption of unit radiation, S_∞ the intensity of the solar radiation outside the earth's atmosphere, ζ the zenith distance of the sun, H the height of the homogeneous atmosphere. It seems plausible, without going into details, that the ion production is proportional to γ and S_∞, and that it increases with decreasing zenith distance. The inverse proportionality with respect to H becomes clear if we remember that H increases with increasing temperature,

$$H = \frac{kT}{gm},$$

where $k = 1.37 \times 10^{-16}$ grad^{-1} cm^2 gm sec^{-2}, the Boltzmann constant, m the mass of the particle, and g the acceleration of gravity. Thus if the atmosphere becomes warmer and expands, the ionization is distributed over a higher layer, and consequently is smaller per unit of volume.

Let us assume that ions and electrons disappear by recombination. If N is the number of electrons or ions per cm^3 we have

$$\frac{dN}{dt} = q - \alpha N^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

where α is the coefficient of recombination and t the time. At noon the value of N is stationary and

$$q = \alpha N^2$$

Thus, if summer and winter values are compared and the value for q in (7) is used,

$$\frac{N_s}{N_w} = \sqrt{\frac{q_s \alpha_w}{q_w \alpha_s}} = \sqrt{\frac{\cos\zeta_s}{\cos\zeta_w} \frac{T_w \alpha_w}{T_s \alpha_s}}$$

H has here been replaced by $1/T$ since it is inversely proportional to the temperature. Introducing the colatitude θ of the place of observation and maximum declination of the sun δ we have for midsummer noon

$$\zeta_s = 90° - \theta - \delta,$$

and for midwinter noon

$$\zeta_w = 90° - \theta + \delta.$$

The recombination coefficient will be smaller, the larger the mean speed of the electrons, or, in other words, inversely proportional to $\sqrt{\tau}$ where τ is the electron temperature, as has been shown by Milne[49]. Therefore, the theoretical ratio between summer and winter noon maximum ionization becomes

$$\frac{N_s}{N_w} = \sqrt{\frac{\sin(\theta+\delta)\, T_w \alpha_w}{\sin(\theta-\delta)\, T_s \alpha_s}} \qquad \ldots\ldots\ldots\ldots (9)$$

Attachment of electrons to neutral atoms and molecules would reduce the seasonal variations[35]. In table IV values obtained from

TABLE IV. Ratio of summer and winter maximum amount of ionization (after Appleton and Naismith)

Place	Latitude	Region	N_s/N_w exp.	N_s/N_w theor.
Slough	51½°	E_1	1.80	1.84
"		F_1	1.86	1.84
Deal, U.S.A.	40° 15′	E_1	1.5	1.47
" "		F_1	1.3	1.47
Washington, D.C.	30° 55′	E_1	1.3	1.44
"		F_1	1.4	1.44

observations at three stations are compared with those following from eq. (9) under the assumption that the seasonal variations of T and τ can be neglected. The good agreement between computed and observed values tends to show that recombination is the most prominent process of electron dissipation, and attachment of electrons to neutral particles is only of secondary importance. This would make it difficult to understand that ions are the cause of conductivity in the E-layer (Cf. p. 353). From table IV and eq. (9) it would appear furthermore that neither the molecular nor the electronic temperature undergoes marked seasonal variations, or that they vary in such a fashion that $T/\sqrt{\tau}$ remains constant, which is improbable.

Martyn and Pulley[40a], however, consider attachment important. They base their arguments on the existence of atomic oxygen in the ionosphere, which is variable with the elevation. More exact information about the presence of atomic oxygen in the high atmosphere will be required before a decision on the importance of attachment is possible.

The behaviour of the F_2-region is different. It has a minimum value of critical frequency at noon and the noon-time critical frequency is rather lower in summer than in winter. Appleton and Naismith consider these variations as real indications of the ionization according to eq. (6), contrary to the opinion of the American workers in this field. Appleton and Naismith explain the different behaviour of the F_2-layer as due to heating through solar radiation which would be more effective in these greater heights with a smaller molecular density than below. This heating causes expansion of the air and spreads the ionizing effect over a thicker layer, thus reducing the ionization intensity per unit volume. If we apply eq. (9) where now N_s is approximately equal to N_w for the F_2-layer, we see that either $T_s > T_w$ or $\tau_s < \tau_w$. The relation between the molecular temperatures is evidently the more likely to occur.

This explanation of the variations in the F_2-layer is opposed by Berkner, Wells and Seaton[48a], according to whom the variations of ionization do not show a difference in phase on the northern and southern hemispheres. More observational material will be necessary before a final decision on this question is reached.

The question whether the ultra-violet solar radiation is sufficient to ionize the upper atmosphere has been studied by Chapman[50]. If the sun is considered as a black body of a temperature of 6000°K., there will be available in the region <1350 A, where the ionization potential is 9 volts, 22 erg/cm²sec., which is a fraction about $1.61\text{x}10^{-5}$ of the total energy. The value 1350 A was chosen since Hughes[51] has been able to ionize air with light of wave-length not shorter than this. These 9-volt electrons are equal to $1.4\text{x}10^{-11}$ erg. This value is obtained from

$$4.77\text{x}10^{-10}\times 9/300$$

since the charge of the electron $e=4.77\text{x}10^{-10}$ and 1/300 is used to transform volt into electrostatic units. Thus $1.6\text{x}10^{12}$ ion pairs per sec. could be generated in a vertical air column of 1 cm² horizontal cross-section. In order to see if this number is sufficient to account for the conductivity of the ionosphere the recombination coefficient α has to be considered. During the night the ionizing agent, i.e., the ultra-violet solar radiation, is cut off, so that eq. (8) becomes

$$\frac{dN}{dt} = -\alpha N^2,$$

or by integration

$$N = \frac{N_0}{1+N_0\alpha t}, \qquad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where N_0 is the number of ions or electrons at sunset ($t=0$). The observations indicate that after 3 hours ($t\sim 10^4$sec.) $N\sim 10^5$. It may be assumed $N_0\alpha t >> 1$ after 3 hours so that eq. (10) may be simplified to

$$N = 1/\alpha t,$$

from which $\alpha\sim 10^{-9}$ is found. This is 1000 times smaller than the recombination coefficient for ions near the ground. At noon, on the other hand,

$$q=\alpha N^2.$$

If electrons are considered as the particles causing the reflection we can put $N=10^6$ roughly. That gives $q=10^3$. (For ions in the E-layer N would be about a thousand times larger, and these considerations would have to be modified.)

Thus, according to observational evidence, 3×10^{10} ions and electrons are generated in a vertical column of 1 cm^2 cross-section and 300 km. in height. This is a smaller amount than could be dissociated by the ultra-violet light of the sun (1.6×10^{12} per sec.). Therefore, the solar radiation is sufficient to account for the ionization of the upper atmosphere.

Fuchs[52] has attempted to determine the temperature of the ionized layer from observations on the reflection of radio waves. The temperature enters in these formulae, as was pointed out, by way of the height of the homogeneous atmosphere. Using noon observations by Berkner and Wells[53], he obtained equivalent temperatures of 400°K. at 190 km. and 1000°K. at 220 km. Estimates by Martyn and Pulley[40a] gave about the same value at 200 km.

VI. The Diurnal Variations of Terrestrial Magnetism

The earth possesses a permanent magnetic field of which the intensity is 5 gauss $= 50{,}000\gamma$. The magnetic poles are the points at the surface where the horizontal intensity vanishes. They are not diametrically opposite, indicating that the field is not symmetrical. The development of the field into spherical harmonics shows that 94% of it is to be attributed to causes inside the earth, 3% to causes outside the earth, while the remaining 3% does not have a potential. A theory of the permanent field is still wanting; the part without a potential is likewise still a riddle. For a first approximation the earth may be regarded as a magnetic dipole with a momentum

$$M = 8.4 \times 10^{25} \mathrm{gm}^{1/2} \mathrm{cm}^{5/2} \mathrm{sec}^{-1}.$$

Superimposed on the permanent field are secular variations which do not concern us here as we are studying the upper atmosphere. There exists a close relation between solar activity and terrestrial magnetism, as shown in figures 6 and 7. (after Bartels[53a]). In fig. 6 the yearly mean of magnetic activity and of sunspot numbers are plotted from 1835-1930. Both curves show clearly the eleven-year period. The parallelism is also found in the monthly means exhibited in fig. 7; a peak in sunspot activity is almost always

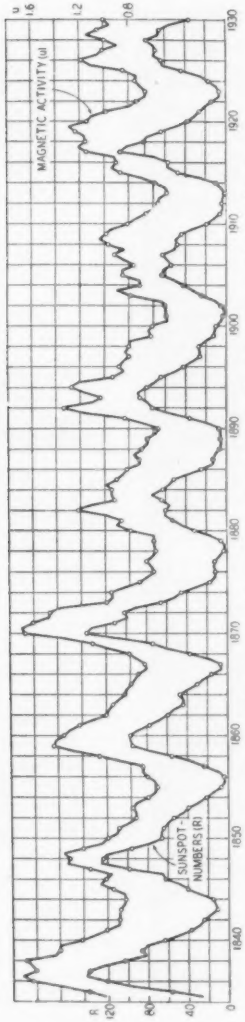

Fig. 6.—Yearly means of sunspot numbers and magnetic activity from 1835 to 1930, after Bartels (Terr. Magn., vol. 37).

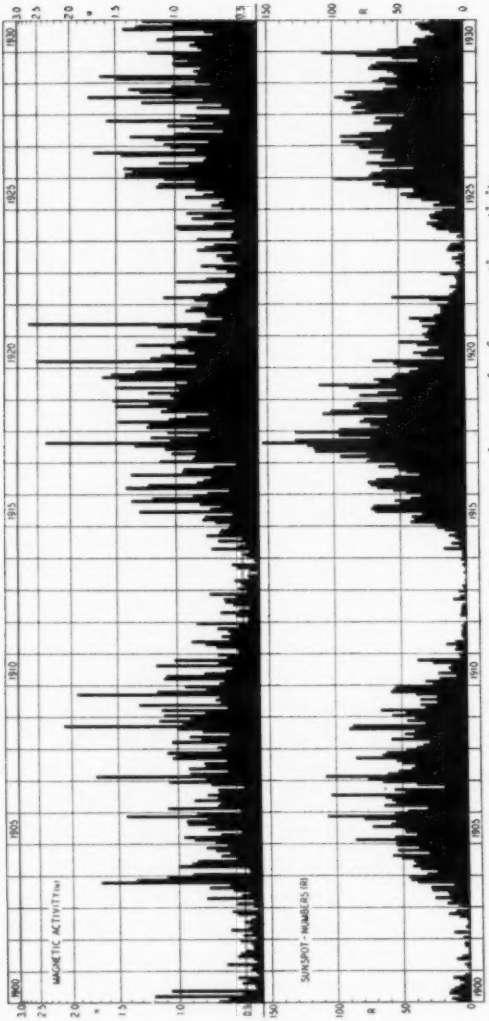

Fig. 7.—Monthly means of sunspot numbers and of magnetic activity, after Bartels (Terr. Magn., vol. 37).

matched by a maximum of the magnetic activity. The magnetic disturbances are closely related to aurorae, as is immediately suggested by their synchronous appearance. According to our present ideas, they are in fact two different manifestations of the same phenomenon. They will be discussed together in the next chapter.

We are here mainly concerned with the diurnal variations of the terrestrial magnetism, for reasons which will soon become obvious. The amount of these variations is about 1/1000 of the average per-

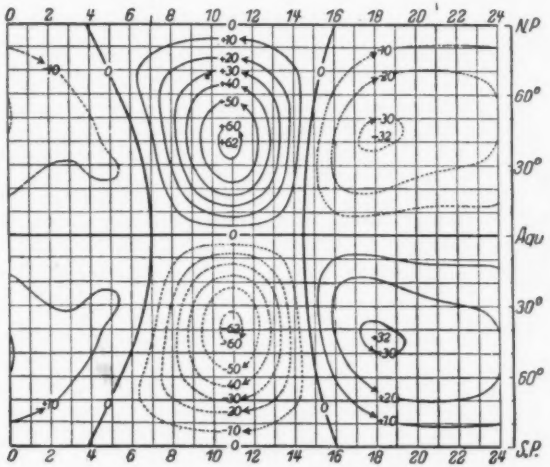

Fig. 8.—Current-system of the daily variations of terrestrial magnetism at the equinox. Meridian given by local noon. Streamlines in distances of 10,000 amperes. After Bartels, Die höchsten Atmosphärenschichten (Erg. exakt. Nat.-Wiss., vol. 7).

manent field. They are different at different places and at different times of the year. The total intensity varies more during the day than during the night.

Mathematical analysis has shown that these diurnal variations are completely expressed by means of a potential and that they must be mainly due to causes above the surface of the earth. Since there is no reason to assume permanent magnets outside the earth these diurnal variations must be considered as magnetic effects of

current systems above the earth, which can be computed in a purely formal fashion with the aid of the electromagnetic theory. The result of an approximate computation by Chapman[54] for the equinox and sunspot minimum is given in fig. 8. There are strong currents on the day-side, positive in the northern and negative in the southern hemisphere. During the night time the currents change sign and are more feeble. With the help of well-known rules the diurnal changes of the magnetic elements can easily be inferred from fig. 8.

Until recently only one theory existed which explained the existence of this current system, the so-called dynamo theory by Schuster and Chapman[58]. When the high conducting layers are

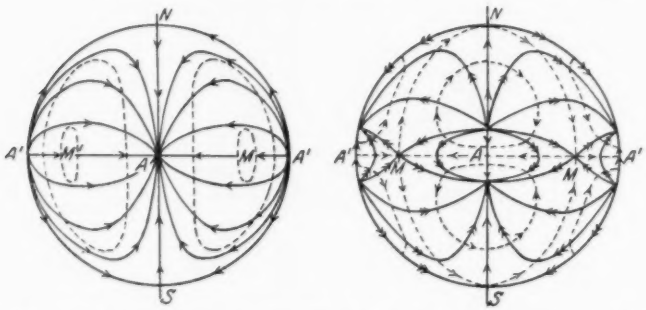

Fig. 9.—Scheme of tidal motions (left) and current-systems (right) causing the diurnal magnetic variations. After Bartels, Die höchsten Atmosphärenschichten (Erg. exakt. Nat.-Wiss., vol. 7).

moved in the earth's magnetic field a current must be induced in them. At the surface we observe the effect of this current as the diurnal magnetic variations. The motions of the high conducting layer are attributed to the diurnal heating and cooling of the whole atmosphere and to the tidal forces of the sun and moon. Thus, by analogy, in the atmospheric dynamo the field of terrestrial magnetism is the magnet, the atmosphere is the rotor and the ionized layers are the armatures.

In fig. 9 the lunar tidal circulation and the resulting electric and magnetic lines are shown in a schematic fashion as given by Bartels[59a]. The left part represents the lines of equal air pressure (dashed) and the lines of air flow. M and M' are the points verti-

cally below the moon, A, A' is the equator. The right part of the figure gives the electric stream-lines and the lines of the horizontal magnetic forces, which are caused by this current system at the surface of the earth.

Since the air motion and the position of the conducting layer are preponderantly horizontal, it is mainly the vertical intensity of the terrestrial magnetism which is responsible for the induction. The vertical intensity is directed upwards at the south pole, zero at the equator and downwards at the north pole. Thus, for higher latitudes the electric stream-lines may easily be derived since air velocity, magnetic and induced electric field form a right-hand system. The lines of magnetic force may then easily be obtained.

The exact theory is of course much more complicated. In the schematic figures it was assumed that the axis of the terrestrial dipole and the axis of rotation coincide, while in reality they are inclined at an angle of 11.5°. Furthermore, the exterior currents induce earth currents which are also recorded. The primary field is 2.5 times as strong as the secondary one. Furthermore, the induced currents vary in intensity owing to the varying conductivity of soil and water. The difference between the pressure oscillations over land and water is another factor which renders the diurnal variation over the whole globe more complex.

The theory shows that the current intensity i is proportional to the specific conductivity σ, the thickness of the conducting layer D, the horizontal velocity u and the vertical component of terrestrial magnetism Z,

$$i \sim \sigma D u Z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

The specific conductivity σ is given by

$$\sigma = n_e \sigma_e + n_i \sigma_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

where σ_e and σ_i are the individual contributions of each of the n_e electrons and n_i ions, respectively. It is

$$\sigma_e = \frac{e^2}{m_e \nu_e} \; ; \; \sigma_i = \frac{e^2}{m_i \nu_i} \; , \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

where e is the charge, m the mass, ν the number of collisions per second. Pedersen[55] has shown that in a magnetic field the conductivity is different in different directions, its value in the direction

of the field (σ) being unchanged by the field, the value transverse to the field (σ_1) being reduced in the ratio

$$K = \frac{\nu^2}{\nu^2+\omega^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

where ω is the angular velocity with which the charge in the absence of other forces spirals around the magnetic lines of force. (Cf. eq. (15)). Equations (12), (13), (14) combined show that σ_1 tends to zero with decreasing ν, while σ becomes infinite. Chapman[54] estimated that the conductivity σ parallel to the magnetic field is mainly caused by electrons, the transversal conductivity σ_1 by ions. The height at which the current flows is, according to Chapman, between 100 and 170 km.

The discussion of the expression for the current (11) is difficult since not only u but also σ changes during the solar day due to the ionizing effect of the solar radiation. It is, however, possible to average out these effects by grouping the observations according to lunar time. In this way we eliminate everything but the variations due to the lunar tide[59]. The amplitude of the lunar diurnal variation is ten times smaller than that of the solar variation. At Potsdam, for example, the lunar oscillation of the declination is 10″. A long series of years has to be worked up to bring out these small variations. Figure 10, following Bartels[59a] shows the result for the magnetic west component at Batavia. The mean of all phases is a simple sine curve. For the different phases the variation is not so simple. In particular, the oscillation is larger during the time while the sun is above the horizon (thicker lines) which we should expect if the solar radiation is the ionizing agent.

It has been calculated from the lunar and solar variations that at sunspot maximum the conductivity of the layer must be

$$\sigma D = 3\times 10^4 \text{ ohm}^{-1}$$

for points where the sun is in the zenith. The nocturnal value is about 1/20 of this. The conducting layer would correspond to an iron shell of 3 mm. thickness in daytime. If $D = 100$ km., the specific conductivity of the ionized layer which produces the diurnal magnetic variations would be $\sigma = 3\text{x}10^{-3}$, while that of the air at the surface is about 10^{-16}. The conductivity of ocean water of $35^0/_{00}$ salinity is $6\text{x}10^{-2}$.

The ratio between solar and lunar variations of terrestrial magnetism is 10:1, as mentioned before, while that between the observed tides at the ground is 16:1, so that the orders of magnitude agree. There is, however, a very considerable phase difference between the computed and observed variations. This might be

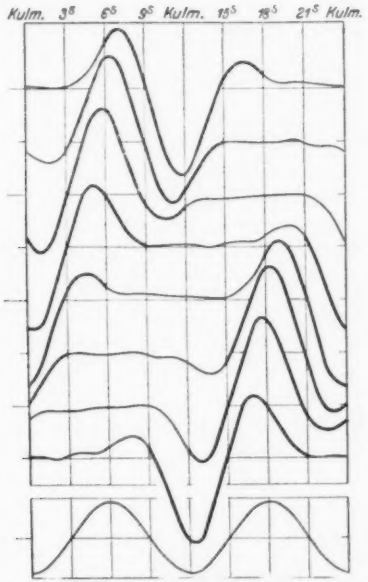

Fig. 10.—Lunar diurnal variation of the magnetic west component at Batavia: for new moon (uppermost curve), first quarter (third curve), full moon (fifth curve), last quarter (seventh curve), mean of all phases (lowest curve) and intermediate phases. After Bartels, Die höchsten Atmosphärenschichten (Erg. exakt. Nat.-Wiss., vol. 7).

explained by internal tidal waves at a surface of discontinuity in the atmosphere, or, as Chapman suggested, by a convective motion associated with the large diurnal temperature variations of the upper strata.

Chapman[54] has published an alternative explanation, the drift

current theory. If a free charge moves under the influence of a magnetic field H the equilibrium between centrifugal and electromagnetic forces requires that

$$\frac{mv^2}{r} = evH \sin (v, H) \ldots\ldots\ldots\ldots\ldots (15)$$

where v is the velocity of the particle, and r the radius of curvature of its path. This gives for the angular velocity ω in circular motion

$$\omega = \frac{e}{m} H \ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

For an ionized nitrogen or oxygen molecule over equatorial regions eq. (16) gives $\omega = 95$ sec^{-1}, approximately. With a temperature of 30°C. the mean ion velocity is 4.7×10^4cm/sec., and hence $r = 500$ cm. The particle moves in a plane perpendicular to the magnetic meridian, downward in the westerly part, upward in the easterly part of its path. Under the influence of acceleration due to the gravitational field and an electric field—which must exist in the upper atmosphere since ions will move somewhat lower than the lighter electrons—the particle acquires a greater velocity moving downward than upward. Thus the curvature will be smaller for the lower part of the path than for the upper part, and on the average an eastward motion will result. The resulting velocity is between 5 and 15 cm/sec. at the equator. Since the number of free charges is greater during the day than during the night a diurnal variation exists. There is, however, also a discrepancy in phase here, but smaller than in the dynamo theory. Cowling[56] showed that the drift current theory has to be modified. Owing to the existence of a vertical pressure gradient it is not permissible to average a velocity at one level with a velocity at another level. According to Cowling's paper, drift currents cannot exist in the stationary state, but they might still be possible if one considers the variations which the earth's atmosphere undergoes.

It is impossible to decide to-day whether the drift-current or the dynamo theory or a combination of both should be accepted. For the lunar variations only the dynamo theory remains. A diamagnetic theory by Ross Gunn[57] would require much too large a number of ions.

(To be Continued)

REVIEW OF PUBLICATIONS

The Druid Bible, by George H. Cooper. 189 pages 9×12 in. San Jose, Cal: Hillis, 1936. Price $5.00.

This is a remarkable book. It aims to supply the solution to many of those problems of the human race which reach back into the mists of time, into the world of mythology, and which for many years have been the subject of research by the archaeologist, the astronomer and the philosopher. The author is very straightforward in his statements. In his preface are the following paragraphs:

> My intent and purpose in this book is to produce evidence that the original of the biblical Eden is Salisbury Plain in England, and that all the ancient stories of all lands regarding the abode and doings of the gods revolve about the conceptions materialized there by the ancient inhabitants of Britain (Atlanteans) which culminated in the construction of the monolithic circles of Stonehenge and the erection of standing stones everywhere observed. Incidentally I account for the ancient civilization of Mexico and Egypt as offshoots of the Atlantean system which at the dawn of British History was known as Druidism.
>
> . . . . . .
>
> Mathematical astronomy is commonly ascribed to the Chaldeans because astronomy had not hitherto been traced further back in antiquity. My solution of the mystery of Stanton Drew, however, disposes of the Chaldean claim in favour of the Druids of Britain.

The author was born in Warwickshire, Eng., in 1859 and in 1862 moved with his parents to Plymouth. At the age of 13 he joined the crew of a trawler fishing off the Cornish coast and followed the sea thereafter. He became very familiar with the coast of Britain and thought he recognized in them the very features of the lands described by Plato and Homer.

Among the questions discussed in the book are Plato's Lost Atlantis, the scene of the Trojan war, the first calendar, the work of the mound builders, the creation story of Genesis, the star maps and astronomy, the Easter Island images, and the mathematics of Old Testament symbolism.

Some of the most ingenious investigations are into sacerdotal numeration, and by the application of the octimal (*i.e.*, with radix 8)

notation he obtains some remarkable results. The octimal notation is considered by the author much superior to our decimal notation.

The conclusions reached are somewhat startling but the facts presented, on which they are based, are numerous and interesting. The present writer has long thought that the well established chronology of Egypt reaches much farther in the past than do any traces of the Druids.

The author has read a great deal and has seen much, always with a keen mind for similarities. It may well be said of him, as it was remarked of Ulysses, "I am a part of all that I have met". He claims much but does it in a modest manner which disarms any harsh criticism. The present writer does not feel himself competent to pass judgment on the validity of many of the conclusions given in the book but it is full of interesting information.

C. A. CHANT

A New Geometry, Analytic—Synthetic, by J. E. Durrant and H. R. Kingston. 238 pages $5 \times 7\frac{1}{2}$ in. Toronto: Macmillan, 1936.

Mr. Durrant is head of the department of Mathematics in the Collegiate-Vocational Institute, Guelph, and Dr. Kingston is head of the department of Mathematics and Astronomy in the University of Western Ontario, London; and this book has been prepared with the schools of Ontario specially in view. It is the product of much experience in presenting the subject. A trial edition printed by the "offset" process was published a year ago and found well adapted to its purpose.

In the book, somewhat relieving the mathematical symbols, is a portrait of Descartes and there are also pictures of objects in which applied mathematics has been much utilized. These include the Ambassador suspension bridge at Windsor-Detroit, and the 74-inch reflecting telescope of the David Dunlap Observatory.

C. A. C.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Observations of Persistent Trains made in Italy

The writer of these notes has recently received from M. Eppe Loreta of Bologna, Italy, a very fine series of visual meteor observations made during twelve nights between July 25 and Aug. 17, 1936. During this period over 1200 meteors in all were recorded, among them three which left persistent trains that remained visible for about a minute in binoculars of 1.75 inches aperture. M. Loreta plotted the drift of these three trains with the same skill displayed in his earlier observation of the same nature (reported in the Journal for July-August, 1936). His plots are reproduced in Fig. 1. In two cases M. Loreta was able to locate a second observation made at some distance from Bologna and the writer has used these to compute the heights of the trains. A graphical adaptation of the Newton-Denning Method[1] of height computation was employed, this being more accurate than working with the average globe. A brief description of the three meteors follows

I. July 28, 1936, 20h 16m G.C.T., mag. −4, duration 2 sec., train duration 10 sec. for naked eye, 100 sec. in binoculars. Observed also by Prof. G. Favaro at Revine, 182 km. away; train duration at Revine (a point much nearer the meteor) 120 sec. for the naked eye. The computation for height gives $H_1 = 110$ km., $H_2 = 70$ km. for the trail as plotted at Bologna. Distance of end of trail from Bologna 272 km., from Revine 123 km.

II. Aug. 14, 1936, 1h 48m G.C.T., a Perseid, mag. 0, train duration 50 sec. in the binoculars. Observed also by Mme. C. Corucci at Livorno, 134 km. away. Computation for height gives $H_1 = 101$ km., $H_2 = 91$ km. for the trail as plotted at Bologna. Distance of end of trail from Bologna 240 km.

III. Aug. 14, 1936, 2h 49m G.C.T., mag. −1, train duration 70 sec. in the binoculars.

Since observations of the train drift were made from only one station the actual magnitude and direction of drift cannot be computed. It is possible, however, to determine a minimum velocity of drift by assuming the train to be moving perpendicular to the line of sight. The true drift will probably be considerably

[1]Proc. N.A.S., vol. 19, p. 209, 1933.

greater. Making allowance for the rotation of the earth during the time the trains were visible and assuming a height of 95 km. for the brightest part of train III, we have the following minimum velocities which indicate strong eastward winds in the upper atmosphere. Considerable deformation is also observed in the case of train I.

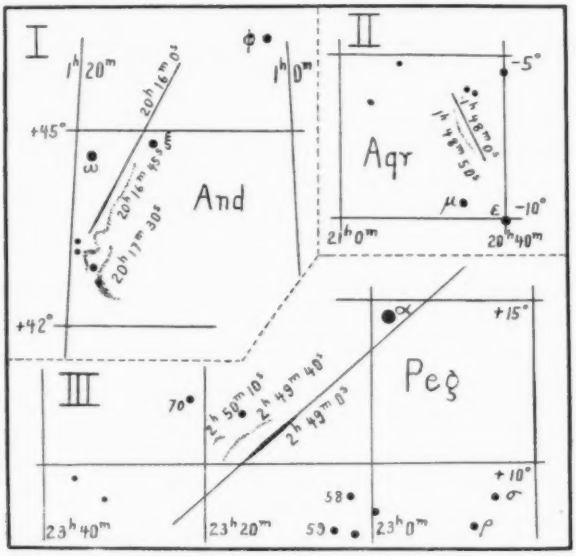

Fig 1. Train drifts for three meteors observed by M. Loreta at Bologna, Italy. Coördinates are for 1855.

MINIMUM TRAIN VELOCITY

Train	I	225 km/hr.	SE	(Ht. 75 km.)
"	II	35 "	E	(" 96 ")
"	III	160 "	E	

The magnitude distribution and total number of trains observed by M. Loreta are tabulated below. Meteor I is not included as it was not recorded during a regular observation period. It is a striking fact that not a single Aquarid train was observed.

MAGNITUDES

Mag.	−2	−1	0	1	2	3	4	5	Total	Mean Mag.
Perseids	1	5	13	39	142	178	193	23	594	2.92
Aquarids				1	18	30	45	5	99	3.35
Others		4	8	15	84	146	204	45	506	3.28

PERSISTENT TRAINS

Duration	1s	2s	3s	4s	5s	6s	15s	50s	70s
Perseids	96	123	41	12	4		1	1	
Aquarids									
Others	12	11	6	1		1			1

P. M. M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Bust of Lord Kelvin for the Smithsonian Institution

The object of the English-speaking Union is said to be "To draw together in the bond of comradeship the English-speaking people of the world." Many interesting lectures are arranged in the various countries by the Union with admirable results; and one of its latest noteworthy acts was the presentation to the Smithsonian Institution on October 8 of a bronze bust of Lord Kelvin, perhaps the most outstanding physicist of the nineteenth century.

The presentation was arranged by the English-speaking Union of the British Empire and the bust was despatched from England on September 23 to the British Embassy at Washington, and Mr. V. A. L. Mallet, counsellor of the Embassy, transferred it to the English-speaking Union of the United States. The Honorable Alanson B. Houghton, formerly American Ambassador to Great Britain, presided at the ceremony as president of the Washington branch of the Union. Acting as the spokesman of this Union, Dr. W. F. G. Swan made the official presentation to the Smithsonian Institution. Dr. C. G. Abbot, the secretary of the Institution, received it and made the following reply:

> It gives me profound satisfaction to accept from Mr. Mallet and the English-speaking Unions of the British Empire and the United States this fine bust representing so great a man. To thoughtful people, who will visit the Smithsonian Institution, which is the foundation of a statesmanlike Englishman, James Smithson, this bust of Lord Kelvin will recall at once the varied, outstanding accomplishments of the greatest physicist of the nineteenth century, including those inventions which made possible the Atlantic cable uniting America with the mother country.

The ceremony took place at a luncheon at the Willard Hotel at one o'clock. The bust is to be placed in a prominent position in the Museum of the Institution. It was modelled in 1902 by the late Herbert Hampton, a famous sculptor and a friend of Lord Kelvin, five years before the latter's death.

The present writer received a special invitation to attend this

pleasing international English-speaking function but to his great regret could not be there. Sir William Thomson was one of the heroes of his boyhood days, chiefly on account of his brilliant services in connection with the Atlantic cable. Later, Lord Kelvin, alone and also combined with Tait, provided him some reading which required considerable thought. In 1897 Kelvin attended the meetings of the British Association in Toronto and by his patient listening to the numerous papers in Section A (Mathematics and Physics) and his generous commendation of the younger scientists he won the admiration of all. He was Professor of Natural Philosophy in Glasgow University from 1846 until his death in 1907 at the age of 83.

Fahrenheit and his Thermometer Scale

The continued popular use of a proper name to represent a common object in time leads the ordinary individual to forget that there ever was a person bearing that name. As instances of this fact one may mention Fahrenheit, Ampere, Macadam; but the 200th anniversary of the death of Dante Gabriel Fahrenheit which occurred on September 16, 1736, has aroused interest in the man and his thermometer. He was born in Dantzig on May 24, 1686. He devised his well-known temperature scale about 1714, and he was the first to bring the mercurial thermometer into general use. He was encouraged in his investigations by a visit in 1708 to the Danish astronomer Römer whom he found placing thermometers in a mixture of ice and water and in bloodwarm water. From *Nature* (Sept. 12, 1936) the following paragraph is taken:

> Fahrenheit was the eldest of a family of three boys and two girls, who were left orphans in August 1701 by the accidental death of both father and mother. He was sent by his guardian to Amsterdam to a merchant's house to learn business, and as a young man made journeys into Denmark, Sweden, Germany and Russia, probably settling finally in 1715 in Amsterdam, where by his lectures he stimulated the study of physical science and where he constructed the thermometers for which he will always be remembered. In 1736 he secured a patent for a mill for draining purposes but did not live to reap any benefit therefrom. His death took place at The Hague, and four days later he was buried in the Kloster kirke, the register of which contains the entry: "Am 20 September 1756

am Tage begraben in dem Gewölbe unter dem Chor Daniel Gabriel Fahrenheit. Für Miete des Grabes und zwei Laüten 18 Gulden".*

It is rather remarkable that the Anglo-Saxon countries commonly use the thermometer scale which bears the name of the German Fahrenheit, while in Germany those oftenest seen bear the name of Réaumur, a Frenchman, or that of Celsius, who was professor of Astronomy at Upsala in Sweden. Of course for purely scientific purposes the Celsius, or centigrade, scale is almost universally used.

Two High-altitude Records

These are the days for breaking records. In connection with the investigation by Dr. R. A. Millikan, of the California Institute of Technology, into the behaviour of the cosmic rays in higher regions, sensitive self-recording electroscopes have been sent up to great heights. Each was carried by five rubber balloons in tandem. These burst on reaching a certain height and the instrument falls to earth, its speed being checked by a parachute. Of five released from San Antonio, Texas, in early July four were recovered. The heights attained were from 55,000 to 92,000 feet or $10\frac{1}{2}$ to $17\frac{1}{2}$ miles, and they were found between 30 and 100 miles from the starting point. They were aloft about three hours. A reward of $6.00 was offered for each instrument returned. An instrument from the greatest height brought back a perfect film. It shows that ionization of the air attained a maximum at a definite height and then returned to lower values as the instrument rose higher.

On September 28 at Farnborough, England, Squadron-leader F. R. D. Swain of the Royal Air Force ascended in his aeroplane to a height of 49,967 feet or $9\frac{1}{2}$ miles. Looking down from a height of 46,000 feet, he said, the light was almost dazzling, but looking up the sky was of the deepest blue, almost black. The aeroplane had a wing span of 66 ft. and a length of 44 feet. Swain wore an air-tight suit to keep the enclosed air at normal pressure and it had a transparent window in the helmet. No special difficulty was

*On the 20th of September 1736 in the daytime was entombed in the vault under the choir Daniel Gabriel Fahrenheit. For rent of the grave and two tollings, 18 gulden.

experienced during the ascent but on coming down the window of the helmet and also those of the cockpit were obscured by frost. He also experienced unpleasant sensations of suffocation and weakness, and was obliged to use his emergency knife to rip open his helmet. He landed safely after a flight of $3\frac{1}{2}$ hours.

Just here one might refer to the record set in August by the steamer "Queen Mary" for crossing the Atlantic both ways, the east-west trip being made at 30.1 knots and the west-east at 30.63 knots, or about 35.7 statute miles per hour. Also to the travel around the earth by regular means of transportation by H. R. Ekins, the New York reporter, who went 25,804 miles in $18\frac{1}{2}$ days.

PROGRESS ON THE 200-INCH TELESCOPE

Intense interest in this mighty instrument continues and the *Scientific American* is serving the public well in supplying authentic information regarding it. In the November issue of that magazine is an admirable article by Captain C. S. McDowell who has been "loaned" by the U.S. Navy to be supervising engineer on the great project of producing and erecting the telescope. Numerous pictures illustrate what has been done and is proposed. These are mostly from air-photographs and from drawings by Russell W. Porter, one of the ablest men engaged on the design of the telescope. A model on a scale of one-tenth has been constructed to assist in studying the operation of the great machine and even it is a large instrument. There are many novel features in the design and these are clearly explained with the assistance of Porter's wonderful drawings. The site for the observatory is on Mount Palomar, 90 miles in an air-line from Pasadena and 45 miles in an air-line from San Diego. Here much work has been done on the foundations and on the water supply. The circular building to house the telescope will be 135 feet in diameter and from the ground to the top of the revolving hemispherical dome the distance will be about 135 feet. The disc for the main mirror is now on its grinding table and it is hoped to finish the task of grinding and polishing it in four years. This estimate may be somewhat optimistic as the task will demand infinite patience and skill, but it is asserted that the mounting will be ready when the mirror is. C. A. C.

MEETINGS OF THE SOCIETY

AT TORONTO

October 6, 1936.—The first meeting of the 1936-1937 season of the Toronto Centre of the Royal Astronomical Society of Canada was held in the McLennan Laboratory, University of Toronto, at 8 p.m. Mr. A. R. Hassard was in the chair.

The feature of the evening was a series of moving picture films, taken by the McMath-Hulbert Observatory, of the University of Michigan, and shown by Mr. Robert H. Combs.

The first picture, "A Trip to the Moon", taken with a 12-inch telescope, showed very clear views of our satellite in most of its phases, and in particular the progressive rising and setting of the sun across some selected craters. The last vestige of sunlight, illuminating the top of a lonely mountain peak, the base of which with its immediate surroundings being in total darkness, was very striking. Very soon, the peak disappeared from view, as the sun sank below its horizon.

Next was shown an occultation by the moon of the star Delta Capricorni, first the disappearance at the dark limb of the moon, and later the reappearance of the star on the illuminated side. It was very curious to see the star suddenly disappear for no apparent reason.

Very interesting indeed was the picture of the total eclipse of the sun in 1932, the film being taken at Fryeburg, Maine. There followed in order the first and second contacts, Baily's beads, and then suddenly the corona, faithfully and clearly defined, burst into view. Close-up, magnified pictures of the solar prominences were shown, their rapid movement outwards from the sun being very apparent.

The final film gave some very beautiful natural colour sunset views, from the most delicate pastel shades to the deepest sombre hues. One picture followed the setting sun from the first colouring of the clouds to the last tinge, when the light vanished completely.

The moving-picture programme was greatly appreciated and much discussion followed. Mr. Combs has promised a further treat to which we shall look forward with pleasure. It is hoped that the other Centres may have an opportunity to see these very interesting films.

Some of the members gave details of their summer observations, and the meeting adjourned.

F. Shirley Patterson,
Recorder.

Royal Astronomical Society of Canada

LIST OF FELLOWS AND MEMBERS

September 1, 1936

HONORARY FELLOWS

WILLIAM WALLACE CAMPBELL, Sc.D., LL.D., Formerly Director of the Lick Observatory, Mount Hamilton, Cal.

SIR FRANK WATSON DYSON, M.A., LL.D., F.R.S., Formerly Astronomer Royal, Royal Observatory, Greenwich, England.

GEORGE ELLERY HALE, S.B., Sc.D., LL.D., Formerly Director of the Mount Wilson Observatory, Pasadena, Cal.

S. HIRAYAMA, Professor in the Astronomical Observatory, Tokyo, Japan.

WILLIAM H. PICKERING, S.B., Mandeville, Jamaica.

FRANK SCHLESINGER, B.S., A.M., Ph.D., Director of the Yale University Observatory, New Haven, Conn.

CORRESPONDING MEMBERS

MRS. A. S. D. MAUNDER, 86 Tyrwhitt Road, St. John's, S.E., London, England.

FELLOWS

CLARENCE AUGUSTUS CHANT, M.A., Ph.D., LL.D., Emeritus Director of the David Dunlap Observatory and Professor of Astrophysics, University of Toronto, Toronto.

JOHN ROBINETTE COLLINS, 253 Wychwood Ave., Toronto.

ALFRED TENNYSON DELURY, M.A., LL.D., Formerly Professor of Mathematics, University of Toronto, Toronto.

RALPH EMERSON DELURY, B.A., Ph.D., Dominion Astronomical Observatory, Ottawa.

F. NAPIER DENISON, Formerly Director of the Meteorological Observatory, Victoria, B.C.

WILLIAM EDMUND HARPER, M.A., D.Sc., Director Dominion Astrophysical Observatory, Victoria, B.C.

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